Beam Diagnostic Instrument Testing at the HINS* R&D Linac

Vic Scarpine, Bruce Hanna, Jim Steimel, Moses Chung, Arden Warner, Christoph Gabor (RAL), and more…

*** High Intensity Neutrino Source**

What is (was) HINS?

*The HINS Linac R&D program is an effort to construct a first-of-a-kind superconducting H- linac. **

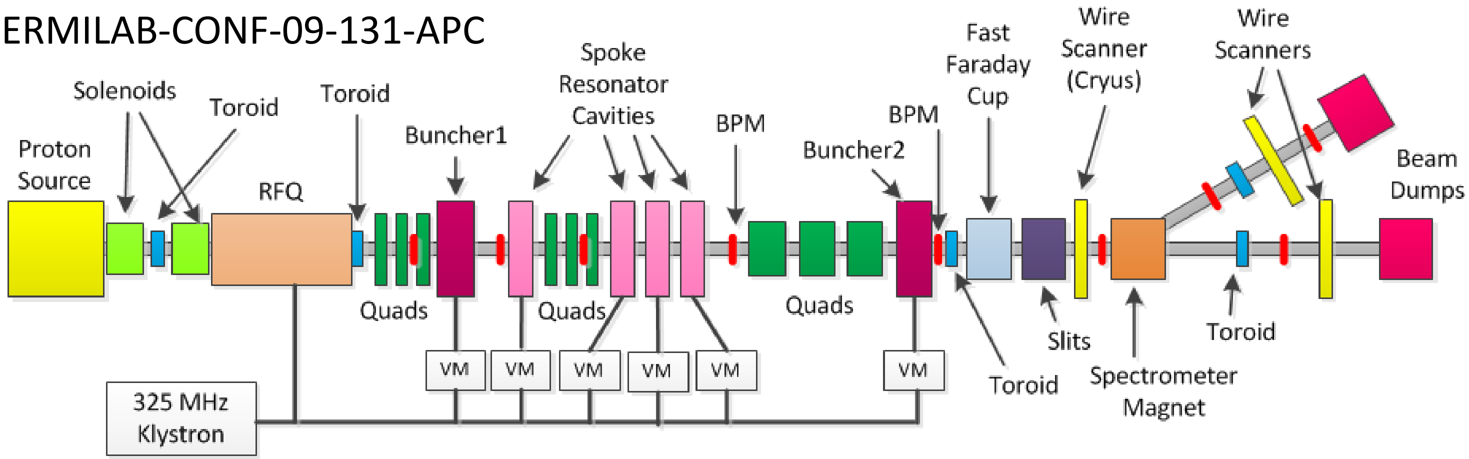
- acceleration of beam using **SC** spoke-type cavities
- high power RF vector modulators for controlling multiple RF cavities driven by a single high power klystron to accelerate a non-relativistic beam
- control of beam halo and emittance growth using solenoid focusing in an axially symmetric optics design
- performance of a fast, 325 MHz bunch-by-bunch beam chopper at 2.5 MeV

* Webber et al, FERMILAB-CONF-09-131-APC

Beam Parameters

Particle	Proton
Bunch freq	325 MHz
Pulse Length	0.05 to 0.2 μsec
Average Current	~ 20 (H, 2H+, 3H+) mA ~8 (RFQ - H) mA
Rep. Rate	Up to 1 Hz
Beam energy	2.5 to 3.0 MeV

Final HINS Beamline



HINS → PXIE

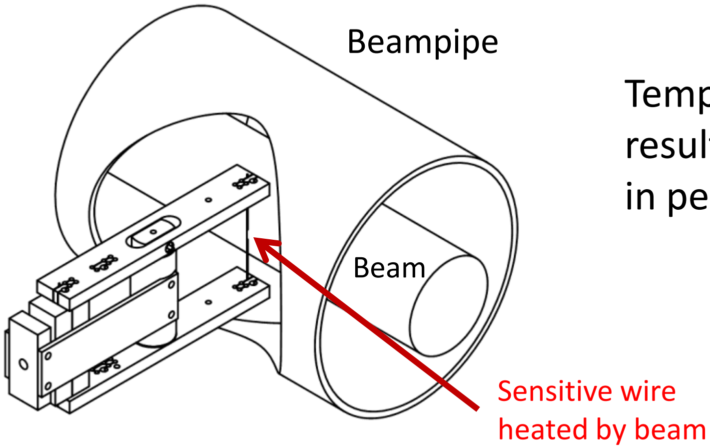
- Initially, HINS was to remain semi-operational until operation of the PXIE RFQ, but because of PXIE budget limitations it was decided to stop HINS operations and use many components for PXIE

Date of HINS final operation was Monday Jan 7, 2013

Before HINS was turned off it was decided to try and make several diagnostic instrument measurements

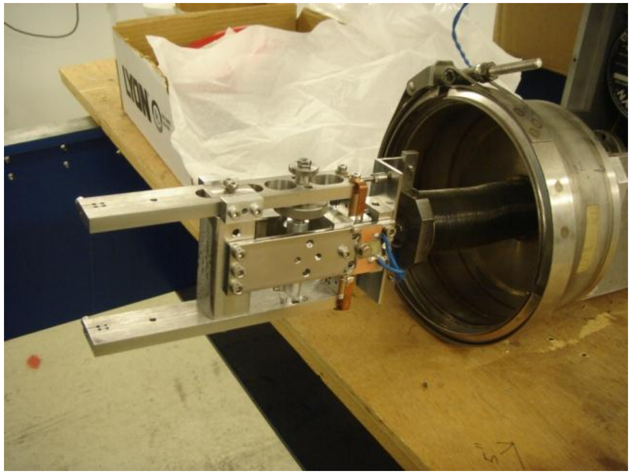
1. Measurement of Transverse beam halo using vibrating wire - Moses Chung, FNAL *– future APC talk*
2. Proton Induced X-Ray Emission (PIXE) for Longitudinal Bunch Shape Measurements - Vic Scarpine, FNAL
3. Low-Energy Proton Loss Monitoring and Single Particle Detection with CVD Diamond Detectors - Arden Warner, FNAL
4. Scintillator Measurements with Low-Energy Proton Beam - Christoph Gabor, RAL & Vic Scarpine, FNAL

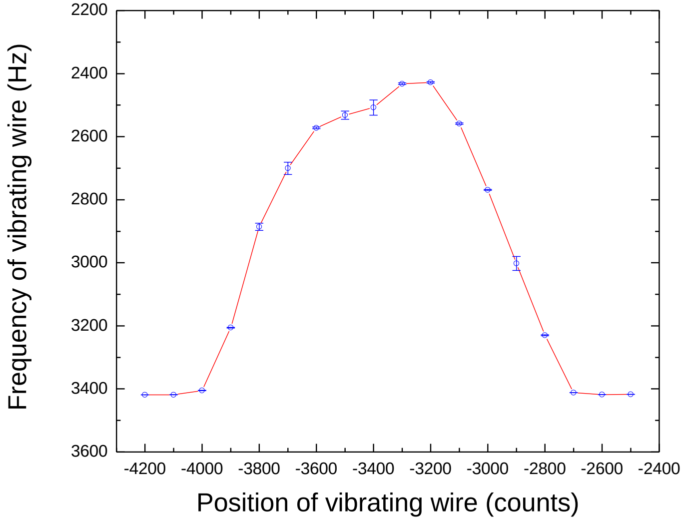
Vibrating Wire Halo Monitor – Moses Chung, FNAL



Temperature change affects the tension of sensitive wire and results in the shift of resonance frequency of the vibrating wire in permanent dipole magnets.

Preliminary measurements made at HINS

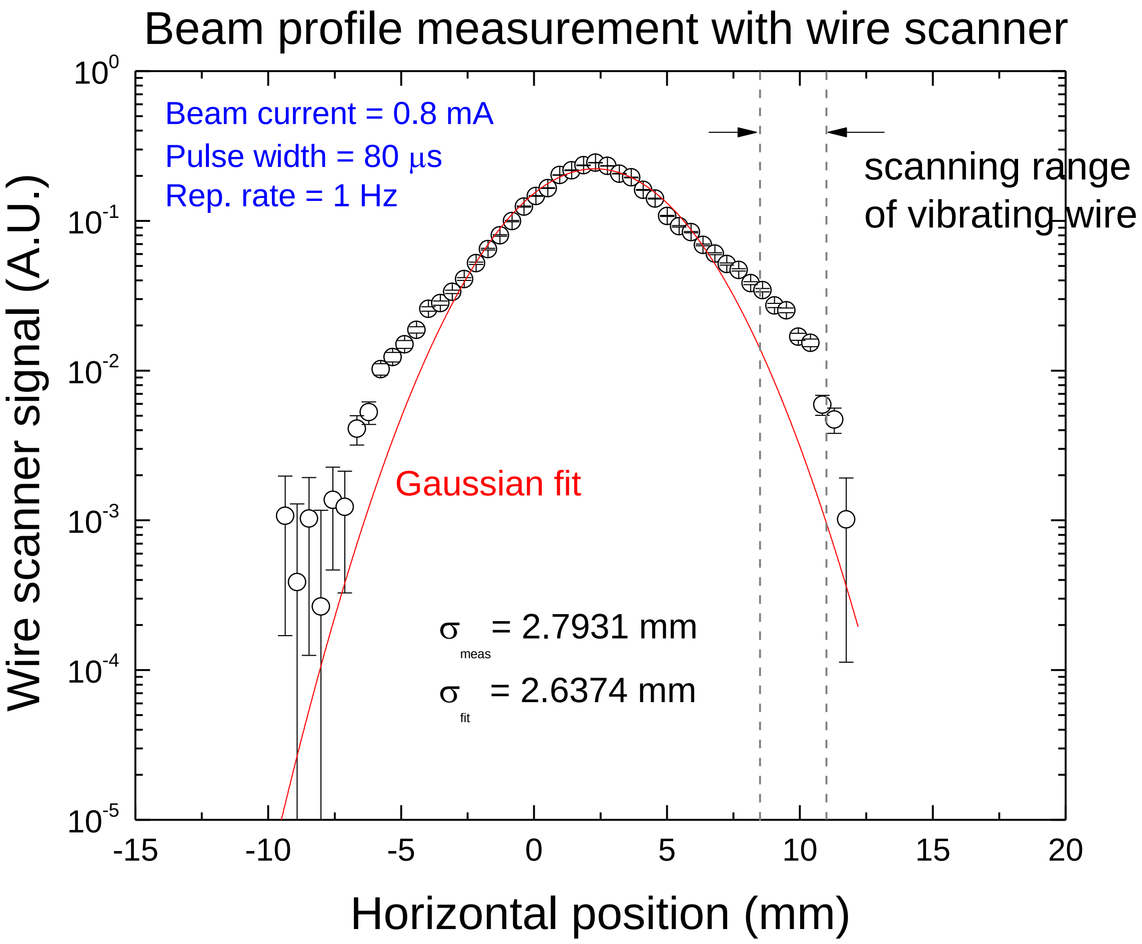


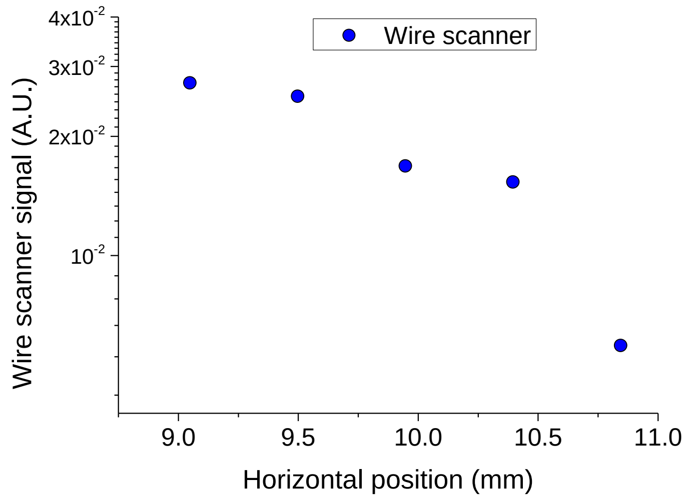


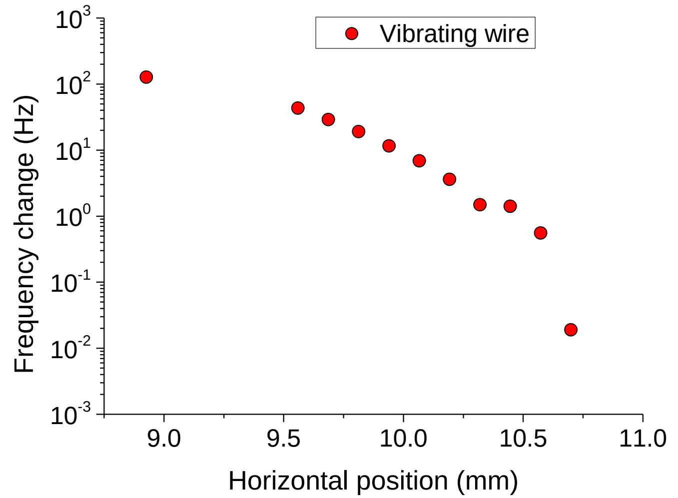
Frequency change is very sensitive to ambient temperature, mechanical vibration, and magnetic field

Comparison between wire scanner and vibrating wire

Preliminary measurements





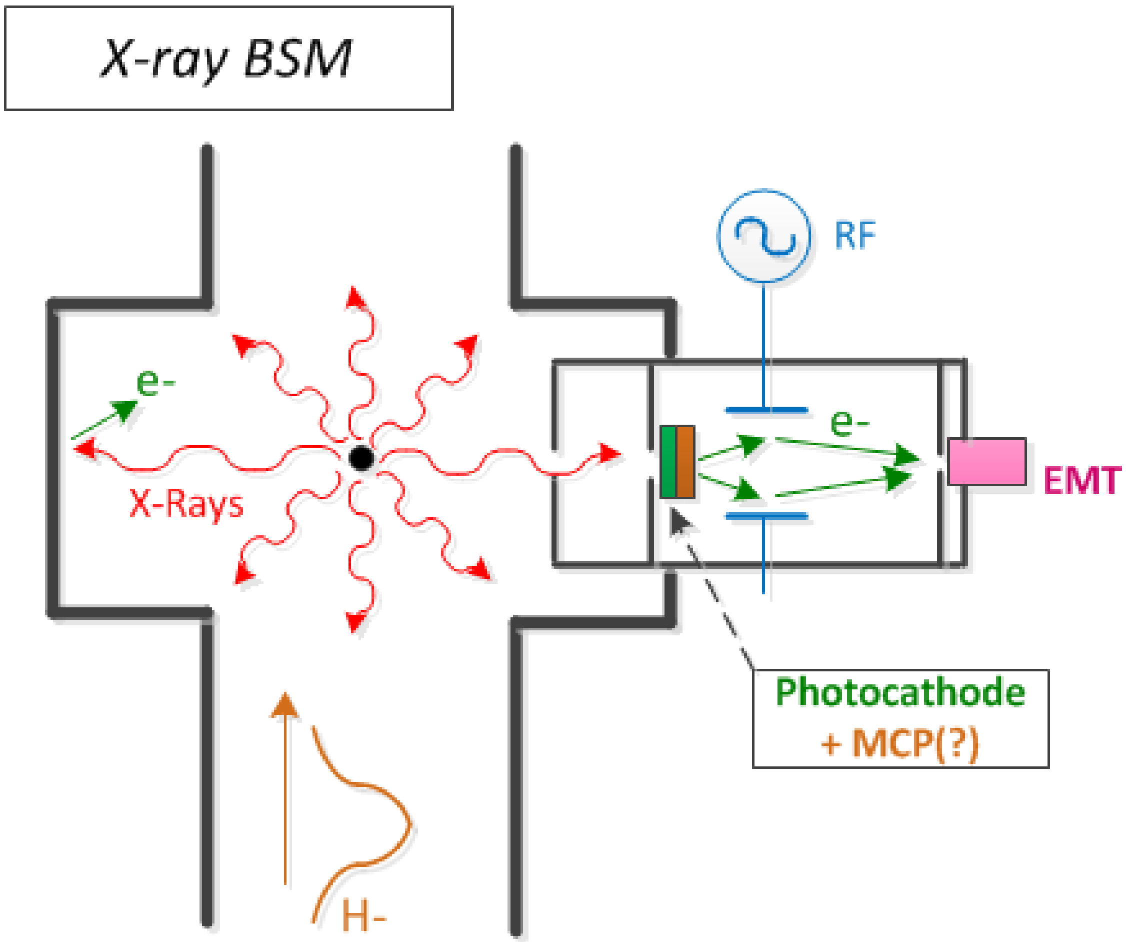


Vibrating wire may have much higher dynamic range in the halo region

Longitudinal Bunch Shape Monitor using Proton Induced X-ray Emission (PIXE) – Vic Scarpine, FNAL

X-ray Longitudinal Bunch Shape Monitor (Ostroumov, ANL)

- Replace SEM BSM with x-ray emission
  - Low-energy H- confuses SEM signal
- Operates like streak camera
  - RF deflecting cavity converts time distribution into spatial distribution
- Gives longitudinal bunch shape
  - *~ psec timing resolution*
  - *may be sensitive to longitudinal tails*
- *What are the responses of different wire materials to low-energy protons?*



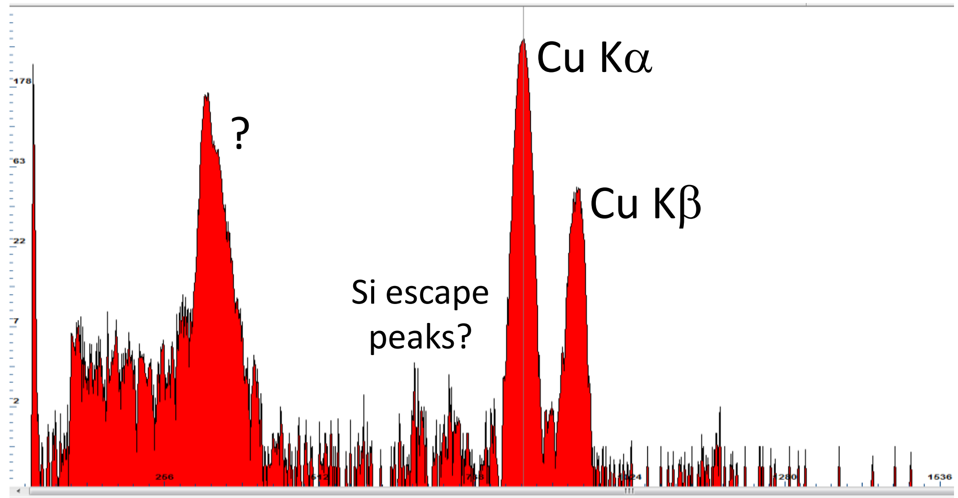
Proton Induced X-ray Emission at HINS

Low-current, 2.5 MeV protons
Amptek low-noise Silicon x-ray detector

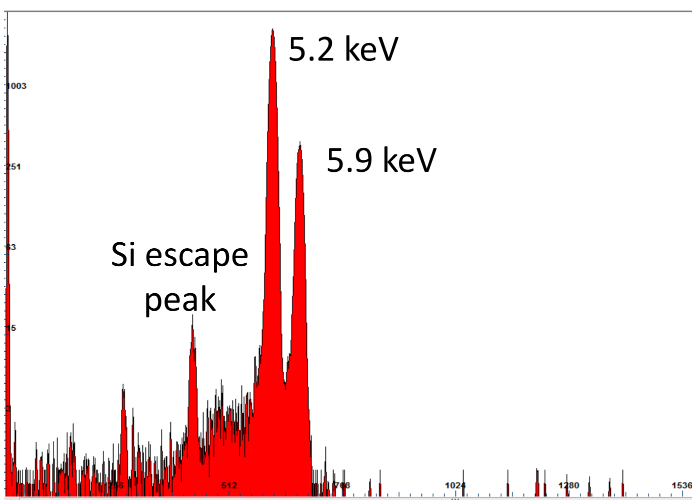
Attempt to measure spectrum and flux for different wire materials

1. 1-mil titanium
2. 2.5 mil BeCu
3. 1 mil gold plate tungsten
4. 3 mil bare tungsten
5. 2 mil Molybdenum

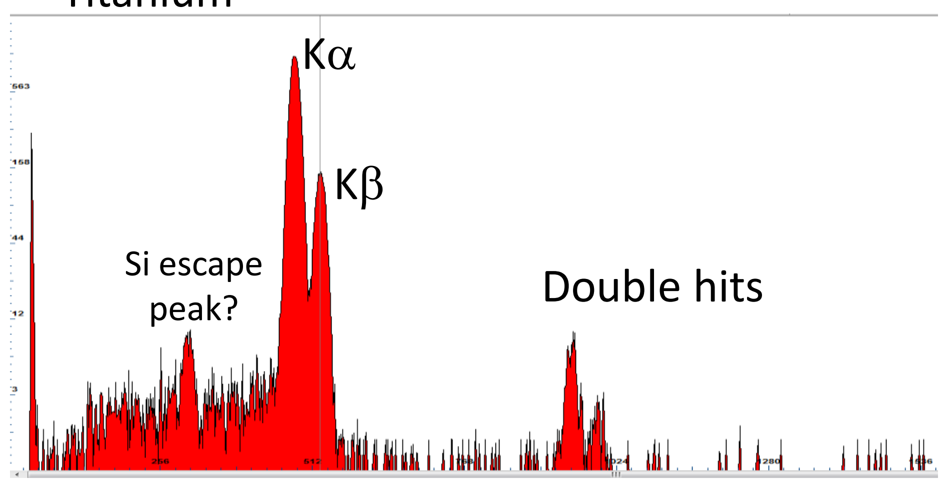
BeCu



Fe-55 calibration source



Titanium



HINS sCVD Diamond detector test – Arden Warner, FNAL

CVD diamonds are being investigated because of their sensitivity to single particles, nanosecond time response and the excellent radiation resistivity which makes them perfectly suitable for applications in high-radiation environments. In addition operation in vacuum at both room temperature and 1.8 Kelvin has been demonstrated.

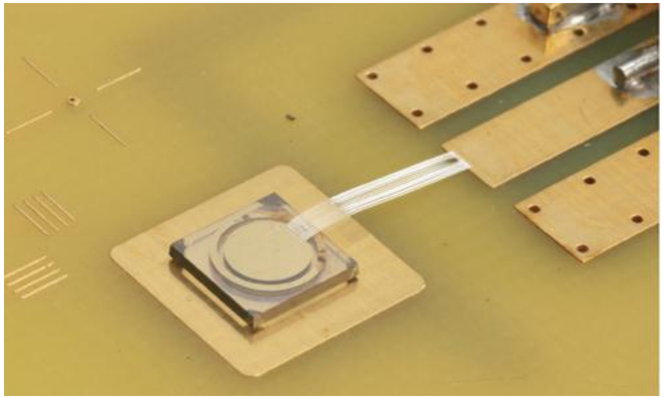
Interest for PIXIE/Project X:

1. Develop an effective loss monitor to detect low energy proton losses (2.1 MeV) as a diagnostic to protect the PIXIE cryogenic system at injection.

2. Provide a detector capable of single particle detection as an effective diagnostic for beam extinction measurements in the accelerator.

Characteristics of crystal that was tested:

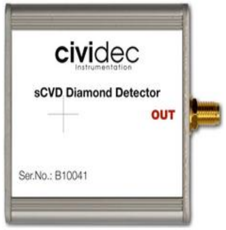
Parameters:	
Substrate material	sCVD diamond
Substrate size	4.6 mm x 4.6 mm x 0.5 mm
Electrode size	4 mm x 4 mm
Electrode material	Gold
Detector capacitance	3 pF
Bias Voltage	500 Volts



Diamond Beam Monitor Response

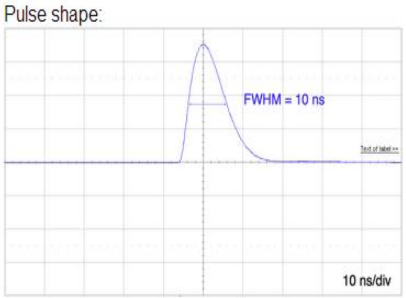
Detector located inside the vacuum with the crystal angled toward the dump. 160 µs beam pulses, 200 µA – 3 mA, 2.5 MeV and 500 volt bias on the detector. Window in case exposes crystal to the beam.

The ideal crystal should be thin (100 micron limit possible dependent on area).



detector

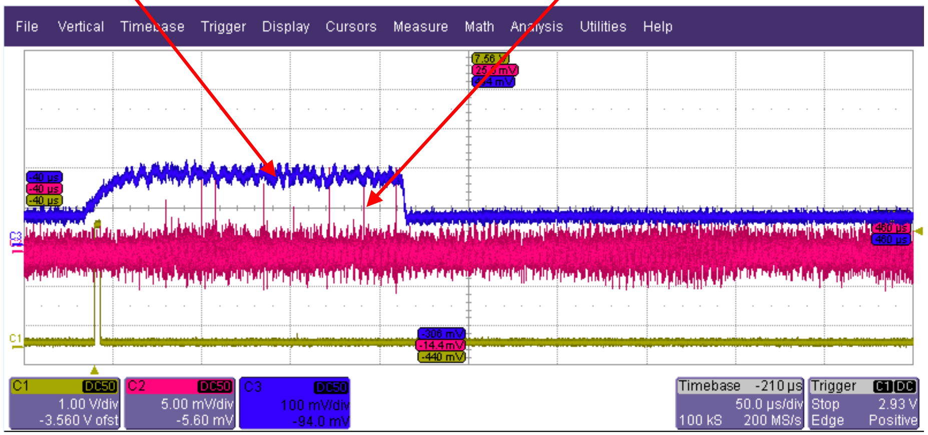
Fast Charge Amplifier: 100 MHz, 4 mV/fC

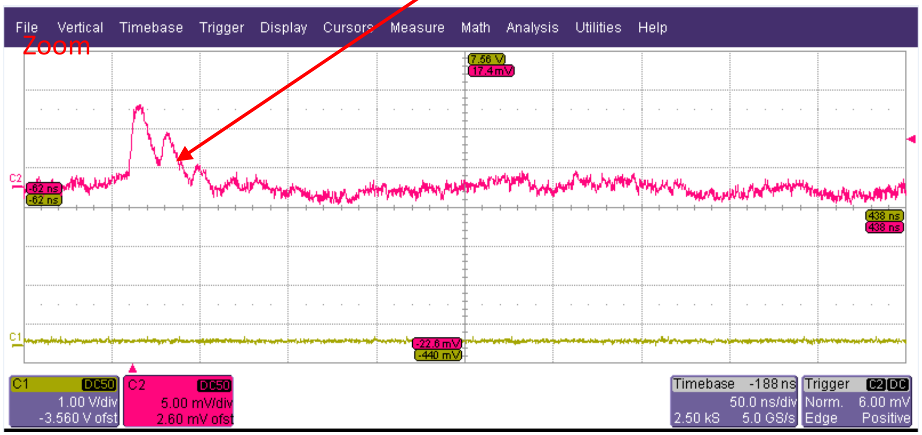


Beam Toroid signal

Single particle detection of scattered electrons and secondary protons from dump

reflections due to cable capacitance is understood and correctable





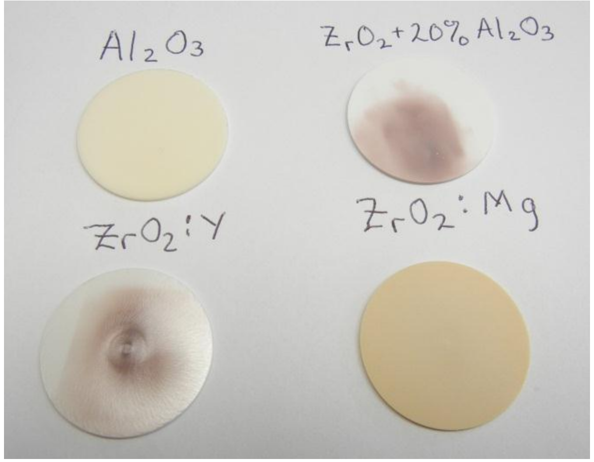
Scintillator Measurements with Low-Energy Proton Beam - Christoph Gabor, RAL; Vic Scarpine, FNAL

Testing of scintillator response for use in laser emittance monitor (for PX/PXIE)

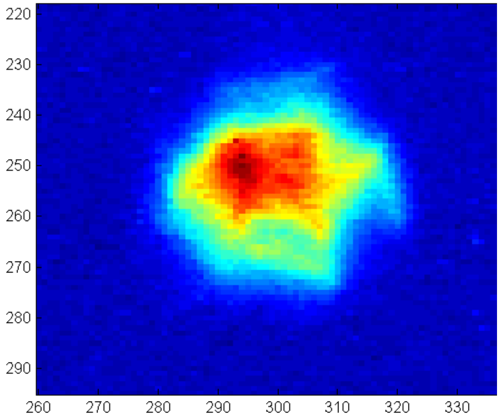
- H- + $\gamma \rightarrow$ H0 + e-
  - Measure H0 distribution to get beam divergence
- Not much empirical data for low-energy beam
- Scintillator damage? Scintillator lifetime?
- Light yield?

- Measure five different scintillators
  - Quartz, Al_2O_3, ZrO_2+20% Al_2O_3, ZrO_2:Y, ZrO_2:Mg

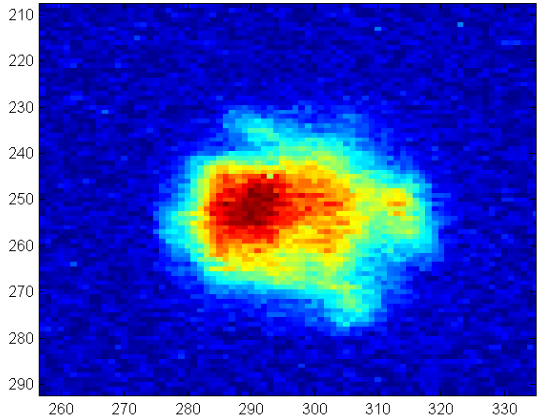
Scintillators after beam



ZrO_2:Mg, 500 μA, ND1, F8



ZrO_2+20% Al_2O_3, 400 μA, ND0, F8



ZrO_2+20% Al_2O_3 after few beam pulses